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BUFFER STRIPS
A POSSIBLE APPLICATION OF DECISION THEORY

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I. Introduction

Current BLM directives (1)(2) require the use of buffer strips on all streams having significant fishery values. This means that the decision maker must analyze and weigh the fishery and timber values on virtually every timber sale that borders on live streams. Many times, the information regarding the value of a specific stretch of stream for the production of fish is nonexistent or sketchy at best. The physical and biological responses of Douglas fir stands to various management practices are usually familiar to most timber managers, but few of these managers are equipped, either by experience or training, to evaluate fisheries. This makes it essential that formal decision-making processes be used in managing wildlands.

II. Background

Before attempting to relate decision theory to the fishery vs. timber problem, it may be well to summarize the current findings on the effects of logging on anadromous fish.

The Alsea Watershed Study provides an indication of the effects of clear cut logging on salmon and trout. The major alterations (3) that occur in the anadromous fish habitat include an increase in the maximum stream temperature and the diurnal temperature range, a decrease in the permeability of spawning gravels and a corresponding decrease in the dissolved oxygen content of the intragravel waters.

The reduction in the quality of the intragravel environment persists for at least two winters after logging, and research is currently underway to evaluate the long-term effects of this degradation. In addition, a decrease in the surface water dissolved oxygen levels was noted during the summer while logging was in progress. This condition was not observed in the following summers probably because debris was cleared from the stream channel immediately after logging.

Figure 1. Stream within buffer strip, Alsea watershed, Oregon

(Photograph by Oregon State University)

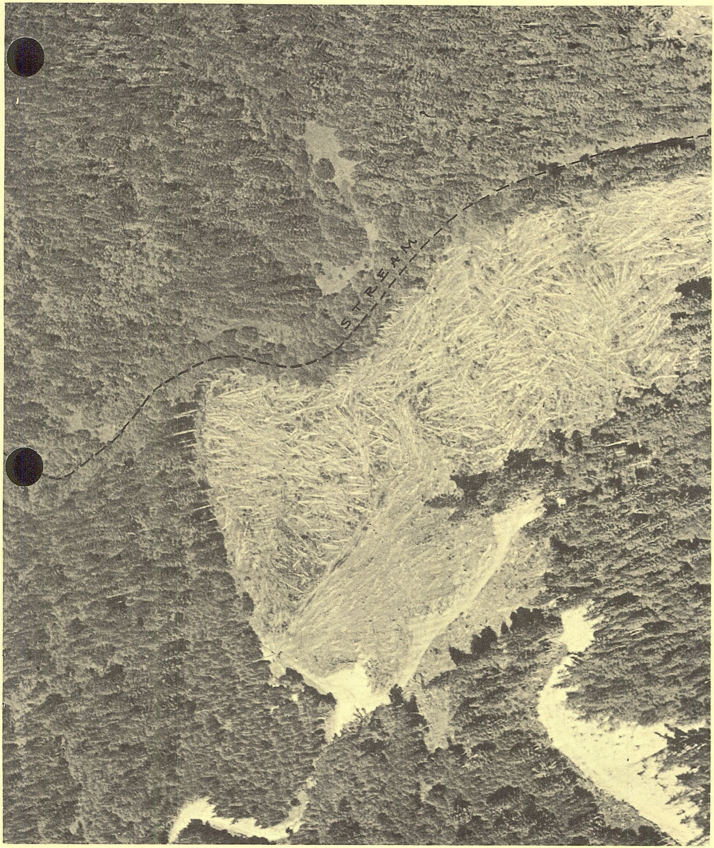

Figure 2. Buffer strip left along stream in the Alsea watershed, Oregon.

(Photograph by Oregon State University)

The Alsea study produced strong evidence that the populations of anadromous fish were affected by clear cut logging. The greatest impact was on the trout; the number of cutthroat trout after logging was only 20 to 25 percent of the number before logging. The impact of logging was much less severe on the coho salmon, however, and the results are still being evaluated (4).

The gross effects of siltation are obvious to even the most casual observer. Some of the more insidious effects are not normally considered, but they may be significant from the headwater areas down through the estuaries and even into the ocean. For example, sediment can cover the stream bottom and decrease the fauna which serves as food for young salmon and trout. It has also been demonstrated that an increasing percentage of fine material in the gravel decreases the number of fry that emerge to the free swimming stage. This is because the eggs and alevins may suffocate and the emerging fry may be unable to penetrate the fine material and make their way upward through the gravel.

In the estuary, sedimentation can decrease the penetration of sunlight which controls the basic production of phytoplankton which is the start of the food chain for young salmonids.

Significant also is the effect that increased water temperature has on a population of anadromous fish. It has been demonstrated that chinook and coho salmon fry acclimated at about 69 degrees F. die if the water temperature reaches 75 to 77 degrees. The ability of water to hold gasses such as oxygen, is inversely proportional to its temperature. At saturation, water at 32 degrees F. can hold 14.6 milligrams of oxygen per liter. Water at 75 degrees can hold 8.5 milligrams of oxygen per liter at saturation. Thus, increases in water temperature result in decreases in dissolved oxygen content which have a marked physiological effect on fish above the critical temperature of about 70 degrees. Coupled with the decrease in vigor that increasing temperatures bring about is the inverse reaction that lower plants and animals such as fungus and pathogenic bacteria have to increasing temperatures. Many pathogens follow the Van't Hoff rule of doubling reaction rates for each temperature increase of ten degrees centigrade over a given range. Thus, increasing water temperatures result in decreased vigor within the fish themselves and increased activity in disease-causing organisms.

III. Analysis

This study will evaluate a proposed F.Y. 1970 timber sale. This sale is planned to be an uphill, high-lead that borders about 3,000 feet of upper Whittaker Creek. For the purposes of this paper, we will assume that the question is whether or not a buffer strip is to be left along the stream.

The first step in the analysis would be the quantification of the value of the fishery resource. A field inspection has shown that the sale will actually border 3,250 feet of Whittaker Creek. The lower 1,000 feet of the affected area is classified as excellent to good spawning gravel for coho salmon. The next 1,000-foot stretch can be classified as good spawning gravel, and the upper stretches can be classified as fair to poor. These classifications of gravel habitat were made by Oregon State Game Commission personnel during a joint inspection of the area.

Since exact quantification of fishery values is impossible with existing information, the following analysis will deal in extremes and work with ranges. For the purpose of the following analysis, minimum values will be used for fishery resources while maximum values will be used for the timber resource. In order to accomplish this, an intentional bias will be introduced at the outset.

TABLE A - Average Stumpage Price, Eugene District

Fiscal Year	Stumpage per MBF
1965	$47.90
1966	$52.19
1967	$45.75
1968	$42.58
1969	$86.74

Table A lists the stumpage prices received in the Eugene District over the past five years. In order to maximize timber values, $150 per MBF will be used as the stumpage value in this report. In addition, the 40 MBF per acre is approximately 25% over the cruiser's estimate of what is actually on the ground.

In order to minimize the fishery values involved, the cutthroat fishery, both anadromous and resident, has been completely ignored. Likewise, the data on which the value of a sport caught anadromous fish (6) is based were collected in 1962. No allowance has been made for the inflationary rise between 1962 and the present time.

The net effect of the intentional bias is to present a situation which gives all possible advantage to the timber resource. Thus, any trade-offs between the fishery and timber resources that may be hypothesized on the basis of the following analysis would tend to have increasing validity as the parameters approach normality.

The use of an intentional bias must be kept in mind in reading the rest of this report as there is danger in attributing absolute values to the numbers used in the illustrations.

Personnel from the Oregon State Game Commission were asked to give an estimate of the minimum number of anadromous fish spawners that the specific stretch of stream would serve under present conditions. It was their opinion that the minimum number would be 44 adult coho salmon. This estimate was based on the fact that Whittaker Creek is similar in size to Flynn Creek on the Alsea Study. Flynn Creek has a 10-year average of 22 spawning females annually. Using a 50/50 sex ratio, a figure of 44 adult salmon using Whittaker Creek annually seems to be justified (4).

The next step is to find the total contribution to the fishery that is represented by these 44 adults returning to the spawning beds. It has been estimated (6) that one adult fish escaping to spawn represents a contribution of 1.2 fish to the commercial fishery. Again using the minimum value principle, it is assumed that another 0.8 fish is provided to the sport fishery for the one adult escaping to spawn. Thus, in this analysis, each adult spawner represents a contribution of two fish to the total fishery. In the example, this would break down to a contribution of 53 coho salmon to the commercial fishery and 35 coho salmon to the sport fishery.

Given these approximations, the next step is to assign a monetary value to these fish. For the commercially caught coho, it would be safe to assume that the 53 fish weighed an average of 10 pounds apiece for a total weight of 530 pounds. The value to the fisherman at dockside of this poundage is about 40¢ per pound (7) for a total value of $212. Please note that this is the value to the fisherman at dockside and does not contain any multipliers for processing or wholesaling. This is roughly equivalent to the stumpage figure which will be used for timber. The 35 sport-caught coho represent $64 apiece (5) for a total value of $2240. Studies have shown that this figure is the amount spent in Oregon to catch one anadromous fish. Summing up, the total annual monetary contribution of the 3,250 feet of Whittaker Creek involved in this analysis is $2452 annually.

In order to make the fishery values comparable to the timber values, the present value of this annuity for a period of 80 years using a 5½% interest rate (8) was $43,964. The use of the 80 year period may warrant further explanation. The fishery resource could be looked upon as a perpetual return and capitalized as such in the analysis. However, the land will be managed on a 80 year cycle as determined by the rotation age of the timber involved. Theoretically, an analysis of this type would have to be made again in 80 years when the second crop of timber is ready for harvest. Likewise, the use of a 5½% interest rate warrants further discussion. It is recognized that the timber industry currently endures interest rates ranging from 8% to 12%. However, long term investments are evaluated and compared within government at 5½% and this rate is used here for the sake of consistency.

Using the maximum values for timber as discussed above, it is estimated that the buffer strip along the 3,250 feet of stream will average 100 feet in width. This would amount to a total of 7.5 acres. Maximum timber volumes on this stretch would be about 40,000 board feet per acre for a total of 300 M b.f. of Douglas fir timber involved in the proposed buffer strip. Using an average stumpage price of $150 per thousand, the present value of this timber volume would be $45,000. The next step in this hypothetical problem would be to analyze the alternatives involved and the various results that could be anticipated under each alternative. For the purposes of this study, I will use three alternatives; namely, a 100-foot buffer strip reserving all timber within the strip itself; a partial buffer strip in which all merch timber is removed but in which no logging will be permitted across the stream itself; and no buffer strip in which the sale boundary is located across the creek and logging takes place without restrictions. Each of these alternatives will be analyzed in light of five different possible conditions. It will be assumed that for each alternative there is a possibility of doing no harm to the fishery, reducing production of the fishery by 20% for a five-year period, reducing the run by 40% for a five-year period, reducing the run by 60% for a five-year period, all with full recovery after the five year period, and obliterating the run entirely.

The first step of applying decision theory to this problem is to construct a present value matrix which is shown on Table 1. This table shows a present value of each of the three alternatives under each of the assumed states of nature. In the case of the 100-foot buffer strip, values shown are those produced by the fisheries only. It is assumed in this alternative that the Douglas fir timber within the buffer strip will not be harvested and thus will provide no monetary returns. The values shown for the partial buffer strip are a combination of the fishery and timber values for each of the various states of nature. The last cell in this row shows the value for the timber only as it is assumed that the fishery has been obliterated. Likewise, the values shown for no buffer strip are a combination of both timber and fishery values except the one cell under the assumption that the fishery run has been obliterated. This table then shows the present value that can be expected under each alternative under the various conditions listed.

TABLE 1 -- Present Value Matrix

Alternatives	Conditions				
	No Harm	20% Reduction	40% Reduction	60% Reduction	Obliteration
100 ft. buffer	43,964	42,079	39,982	37,890	- - -
Partial buffer	88,964	87,079	84,982	82,890	45,000
No buffer	88,964	87,079	84,982	82,890	45,000

The probability matrix (Table 2) shows the probability of the various states of nature occurring for each alternative. For example, it is estimated that nine times out of ten no damage would occur to the stream using a 100-foot buffer strip while there is a one in ten chance of reducing the runs by 20%. Using no buffer strip, it is estimated that we have a five out of ten chance to reduce the runs by 60% and a three out of ten chance of destroying the runs entirely. Please note that these are probability estimates for this specific stretch of stream at this point in time. If the decision maker lacks empirical data, he will have to make a similar estimation for each individual case.

TABLE 2 -- Probability Matrix

Alternatives	Conditions				
	No Harm	20% Reduction	40% Reduction	60% Reduction	Obliteration
100 ft. buffer	.9	.1	0	0	0
Partial buffer	.1	.2	.4	.2	.1
No buffer	0	.1	.1	.5	.3

An explanation of the ground rules that apply to the use of decision logic tables is in order here. A probability between 0 and 1 (0 meaning that it is impossible for the event to occur and 1 meaning it is a certainty that the event will occur) must be assigned to each condition under each of the alternatives considered. The sum of the probabilities assigned to the conditions for each alternative must equal 1 (9). These rules must be followed if this method is to be used.

The next step is to construct a pay-off matrix which is shown as Table 3. The values shown in this matrix are obtained by multiplying the present value shown in each individual cell in Table 1 by the probability shown in the corresponding cell in Table 2 and entering the result in the corresponding cell in Table 3. This table should then show us the expected pay-offs from each of the alternatives under each of the assumed conditions using the probabilities we have assigned.

TABLE 3 -- Payoff Matrix

Alternatives	Conditions					Total Expected Payoff
	No Harm	20% Reduction	40% Reduction	60% Reduction	Obliteration	
100 ft. buffer	39,567	4,208	-0-	-0-	-0-	43,775
Partial buffer	8,896	17,416	33,993	16,578	4,500	81,383
No buffer	-0-	8,708	8,498	41,445	13,500	72,151

IV. Interpretation

One important item must be clarified before attempting to relate the information developed above to an actual decision making process. Our analysis deals only with the interaction between the anadromous fishery and the timber resources. A drastic activity like a clear cut timber sale has a great impact on a complex ecological system. The analysis developed here deals with only a few of the many inputs into the decision making process. The decision maker must also deal with aesthetic, watershed, water quality, social and political factors in arriving at his final decision.

One item that becomes immediately apparent is the fact that, in this case, the present value of the anadromous fishery ($43,964) essentially offsets the present value of the timber ($45,000), even using highly inflated values for the timber and ignoring the increased logging costs that would be inherent in a full or partial buffer strip. Many foresters are unwilling to acknowledge this point, although in actuality it is probably a fairly common occurrence. The question is not one of fish or timber. The two resources are not necessarily mutually exclusive, and the job of the decision maker is to determine which alternative will give the greatest return from a combination of the two resources.

The decision logic tables developed here can help in making this determination. By adding the pay-offs for each alternative (9), we get a total expected pay-off as shown in Table 3. Thus, the partial buffer alternative gives us the highest expected pay-off ($81,383).

The decision maker must be familiar with how the three matrices were developed. For example, the cell for no buffer and a 20% reduction in fish shows a pay-off of $8,708. At first glance, it would appear as though the timber were being ignored because under the no buffer alternative, we would be assured of a timber return of $45,000 regardless of which condition occurred. However, Table 1 has the full timber value entered for each condition. The probabilities in Table 2 add up to 1, therefore, the total expected pay-off in Table 3 contains the full timber value for the no buffer alternative. The analysis shows two defensible courses of action. It does not indicate which is the best alternative to adopt. This is where the decision maker comes in. He has a fully developed analysis to work with, but this does not relieve him of the responsibility for making a decision and living by its consequences.

One obvious course of action would be to adopt the partial buffer alternative. As shown in Table 3, this alternative would give us the highest total expected pay-off in the long run.

The prudent decision maker should also look at Table 2. He should realize that with the partial buffer alternative, he has a one in ten chance of obliterating the fishery entirely. He may not be willing to take this chance, in which case he may conceivably choose the 100 ft. buffer alternative. Here, he realizes he is sacrificing the timber returns, but he has a nine out of ten chance of receiving a fishery income which offsets the timber value. Thus, the decision maker, with his insight and expertise, remains the key element in the process.

V. Discussion

It must constantly be borne in mind that the decision theory application shown above is an aid to the decision maker rather than a decision producer. There is no process which can be cranked through and expected to turn out the best management decision. The value of the process outlined above is that it lays out all of the alternatives and allows a decision maker to base his decision on something besides intuition or personal preference.

The raw economic data in the above matrices must be tempered by the decision maker's best judgment of the other values concerned, be they environmental, social or political. For instance, the above analysis makes no provision for such things as water quality. Environmental standards may make it necessary to go with the 100 foot buffer strip and make water quality an overriding consideration. Also, using the principle of minimum fishery values, no attempt was made to include the returns provided by the cutthroat production of the area. This would be both a return from the anadromous variety and a return from the native variety. It is extremely difficult with available information to quantify this resource. However, it must not be overlooked by the decision maker during his evaluation process. It must also be pointed out that the 1962 fishery data was not increased by the inflationary rate.

The one thing that is shown clearly by the above analysis is that from an economic standpoint, the fishery values can equal or exceed the timber values. In actual practice, timber values are often heavily weighted to the extent that no other considerations are made in instances where significant timber volumes are involved. We can no longer afford the luxury of such shortsighted decision making.

It is obvious that many of the figures used in the above tables are estimates. The lack of reliable fishery data is one of the most critical managerial problems we have today. However, we cannot use the lack of reliable data as an excuse for disregarding substantial fishery values. We must make use of all the techniques available to us and make our best judgments until empirical data are available.

VI. Summary

Basic decision theory may prove very helpful in equating fishery and timber values. It is a simple, step-by-step process which allows a decision maker to display all of the available facts and incorporate his best judgment where facts are lacking. It does not in itself present a solution to any problem, but it assures that the decision maker gives full consideration to all resource values and is basing a decision on an objective analysis rather than an intuitive guess. It is felt that a documented analysis of this sort should be made a requirement of the justification for all timber sales that are adjacent to streams having fishery values. The values involved with anadromous fish habitat have

gone largely unnoticed, yet they are significant and increasing. An Oregon State Game Commission study on Lost Creek, which is a tributary of the McKenzie River, estimates the value of one acre of spawning water to be $10,000 per acre annually. The Bureau of Commercial Fisheries in Oregon and Washington has spent up to $218,000 per acre to construct artificial spawning beds to replace those natural beds which were lost. We must insure that we protect all of our remaining natural habitat to the fullest extent possible.

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